

"INSECTS AND DISEASE."

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Dr. Elkington said:—The subject upon which I have been asked to address you this evening is one which has, within the past six years, produced a profound alteration in several branches of science. Here in Tasmania we are fortunately free from those scourges of humanity which are as yet known to depend wholly for their spread upon the agency of insect life, but even with us the problem is not wholly one of outside interest, as I will endeavor to show you in relation to typhoid fever. In this case, however, the method of conveyance is purely a mechanical one, due to particles of infected matter clinging to the legs and bodies of flies, and subsequently deposited upon food material, whence it is taken into the alimentary canal of the victim. It is advisable, therefore, to clearly distinguish between the two methods in which insects play a part in spreading disease amongst human beings, whether—

(a) As carrying agents pure and simple, the infecting agent undergoing no change and not being dependent on the insect in any way.

(b) As hosts, intermediate or definitive, the infective organism being dependent upon the insect and undergoing an extracorporeal phase of development in its tissues.

The first group is of distinct importance from the sanitarian's point of view, in that it teaches us to guard against a real danger in times of prevalence

of certain infectious diseases, but the second one far outweighs it. Into this second group fall some of the chief scourges of mankind, in tropical regions at any rate, and of these the greatest is malaria. Next to tuberculosis, malaria is probably the greatest cause of death and of ill-health with which mankind has to contend. Some of you have, no doubt, visited or lived in places where malaria, or even Yellow fever, have claimed their yearly toll of lives and health, have seen the long white-washed wards and wide verandahs of an Indian Cantonment Hospital filled with pasty-faced fever-stricken soldiers, and have heard day after day the drone of the regimental bands along the dusty white roads to the cemetery. To that supreme critic of all our actions, the "man in the street," the proof of the conveyance of malaria by the agency of certain species of mosquitoes was merely an interesting piece of knowledge, but to those who know what the disease in question really means, it was a fact of startling importance, presaging the approach of effective means of checking an enemy which in the year 1897 alone laid 75,821 British soldiers by the heels in hospital out of a total strength of 178,000 odd in all India. I need hardly remind you how nobly the promise of that great discovery has been fulfilled, how "the white man's grave" of former years has become the white man's sanatorium, and how it is now possible for the march of

Anglo-Saxon civilisation to progress in places where even six years back a new-comer could count his reasonable expectation of life on the fingers of one hand. Tropical medicine has assumed such great proportions that it practically forms the pivot upon which turns the whole question of European colonisation in the tropics, and, practically speaking, tropical medicine is very largely based upon the spread of disease by insects. There, freedom from malaria practically means freedom from ill-health. The London and Liverpool schools have received noble recognition from Mr Chamberlain, and from hard-headed business men who can see into the future. Many a Peter the Hermit is leading a crusade against disease with knowledge, and often with funds supplied in this way, enabling the British race to get on a step further with colonisation. America has taken up the work with especially striking results in relation to Yellow fever, and a handful of workers succeeded in clearing Havana of this fell disease in ninety days—after it had had an uninterrupted reign for 140 years. The discoveries which have been made are, I think, but a foretaste of those which are to come, but their histories, with the patient record of constant toil over minute details, of the sacrifice of leisure and recreation, and even in some cases of the lives of the workers for the furtherment of knowledge, form, to my mind, one of the noblest romances ever written. The work of Manson, Ross, McCallum, Reid, and others have revolutionised the methods of research into human disease, and there is little doubt that we are on the verge of further great discoveries in which the lower forms of life will be found to play an essential part in disease affecting mankind. But this may appear to be something of a digression from the practical treatment of my subject. I trust, however, that I have shown you to some small extent the importance of the results obtained, and the possibilities which they open up. I will now endeavor, with the aid of a few lantern slides, to indicate in some measure the manner in which these discoveries have been made, the difficulties against which the workers had to contend, and the method in which they are practically applied.

The classical example is, of course, supplied by malaria, or paludism, as it is often

termed. As I need hardly point out, both these terms indicate the association with the presence of marshes, swamps, and other wet-soiled localities, which has been for centuries noted in connection with the disease, malaria meaning merely "bad air," and paludism the condition induced by marshes. Now, about the middle of last century, certain observers noted the presence of certain brown and black granules in great numbers in the blood and organs of malarial patients, and in 1880, Dr. Laveran, a French military surgeon in Algeria, made the discovery that the black granules, which are known as melanin, were produced by the action of immense numbers of tiny parasites living in the red blood corpuscles. This was a very notable discovery, as it naturally caused enquiry into the manner in which the parasites got into the blood corpuscles, and once there how they produced the fever. It was found that they could not be grown on artificial media, even from blood which swarmed with them, and other discoveries soon made it clear that they represented a distinct form of animal life, and not a vegetable one, like the bacteria for instance. Some five years later another discovery was made, namely, that these parasites breed in the blood, and that the attacks of fever coincide with the breaking up of the cluster of spores so formed. It was also found that three varieties at least of the organisms infect men, and that yet others were to be obtained from the blood of birds, bats, cattle, monkeys, and other animals.

(A picture was then shown of one form of malarial organism as it appears under the microscope in the various stages of development, which are traceable in the blood so long as it retains its vitality after removal.)

Under the microscope, the strange octopus-like creature, which represents the last stage of development in blood specimens, would attract your attention even more than in the lantern pictures, since its arms are in vigorous motion from the time they shoot out from the surface. If kept moist and warm another strange phenomenon occurs. One or more of these arms will be seen to sepa-

rate itself from the body and to shoot vigorously away. So vigorously, and with such apparent intention does it do so, that it often sets the surrounding corpuscles bobbing like a row of corks in a tideway. For years a discussion raged over this phenomenon. Why did the organism throw out these arms only after leaving the body? The octopus-like creature, or male gamete, was never seen in blood immediately after its removal, but developed from certain of the parasites, but not all, in a short time when kept warm and moist. If not kept warm and moist it did not develop. Moreover, why was it that only some of the amoeboid organisms threw out arms and not all? And why did one or more of the arms when thrown out cast loose from the rest and dart away?

Upon these and similar facts Dr. Manson, then of Hong Kong, formulated in 1894 that fine piece of inductive reasoning which will always be associated with his name. Earlier observers had from time to time made suggestions of a similar nature, but it was reserved for Manson to formulate from the known facts a true scientific hypothesis. Being a parasite, he argued, the malarial organism must, like most other parasites, live for part of its existence outside the human body in another host. The octopus-like male gamete does not come into existence until after leaving the body, and while in the body the parasite is incapable of liberating itself by its own efforts. No traces of the parasite could be found in any of the discharges of the patient. It was therefore probable that it was removed from the body by some blood eating creature. Manson had previously performed some brilliant researches into the conveyance of certain other blood parasites by mosquitoes, and he was led to the conclusion that some distinct kind of mosquito was the probable agent, and that the male gamete formed the first stage of the extra corporeal development of the parasite in its new host. I need scarcely remind you that in all its main points Manson's hypothesis has been proved correct.

Then Captain (now Major) Ross, of the Indian Medical Service, took up the work of investigating the development in the mosquito. It must be remembered

that he began with practically no knowledge of the classification, structure, or habits of mosquitoes, since at that date (1895) comparatively little was known even to dipterologists, and that most of his work was done in an up-country Indian station far from the equipment and facilities of a modern laboratory. For two and a-half years he worked on, dissecting and examining, cell by cell, hundreds of mosquitoes without result, and attempting feeding experiments in vain. It is natural that after such an extended series of negative results he was beginning to suspect a flaw in Manson's theory. Then came light. A peculiar species of mosquito, which he had once before noticed in a very malarious locality as possessing dappled wings and laying boat-shaped eggs, was fed upon the blood of a malarial patient, and on dissecting it he found, for the first time, in its tissues granules of that coal black substance which I mentioned as being called melanin, and as characteristic of malarial fever, and in its stomach walls certain oval cells. These discoveries practically solved the problem. The dappled winged mosquito with boat shaped eggs belonged to the genus *Anopheles*, and the oval cells in the stomach wall were the developing parasites of remittent malarial fever.

The rest was comparatively easy once these facts were known.

The plague scare amongst the natives made it necessary for Ross to pursue his researches into the development of the organism in the mosquito by means of a closely similar organism conveyed by a *Culex* to birds, since blood feeding experiments from human beings became practically impossible, but he had solved the two great problems in the way of the triumphant proof of Manson's hypothesis, and that hypothesis was proved to be soundly founded. He had, moreover, distinguished the true malefactor—the *Anopheles* mosquito—from the innocent *Culex*, and his previous difficulties were to some extent explained by the silent retiring and unobtrusive habits of the former genus. The differences between *Culex* and *Anopheles* are clear enough nowadays, but it is proverbially easy to be wise after the event. We must always remember Ross in his up-country bungalow working on without recognising this shy and unobtrusive genus, from the myriads of *Culices*

The differences are well exemplified in the lantern slides, which I will now show you, and they extend through the insects' lives from beginning to end. In the first place they may be readily enough distinguished by the attitude assumed in resting. *Anopheles* seems always to be endeavoring to stand on its head, while *Culex* rests parallel with the surface in a hunched up position. This, of course, is a rough test, but after a little while one becomes very expert in distinguishing the two in a locality where *Anopheles* are present. I may state that I do not know that any species of *Anopheles* existing in Tasmania, although one species has been recently described as existing in Victoria. I have not come across a member of the genus in a large number of mosquitoes lately examined in Tasmania. All species of *Anopheles* are not capable of conveying malaria, a fact which explains the presence of this genus in non-malarial localities where cases are from time to time introduced. The female, by the way, is usually the blood-sucker amongst mosquitoes, a meal of blood being stated to be essential for the fertilisation of the eggs. The male, except in the stegomyia and a few others, is an innocent creature, preferring a vegetable diet of fruit juices, if indeed he does feed at all, and not, like his partner, varying it with animal food extracted in a voracious and annoying manner.

Both male and female are here shown, but, taking the latter first, you will note the length of the palpi—as long or longer than the proboscis. This is in itself, in the female, a mark of the genus. The wings are spotted in both specimens—another fair but not infallible guide-mark to the *Anopheles*. Turning to the male, you will note that the palpi are also long, but they are always long in the male, whether of *Anopheles* or *Culex*. These, however, are clubbed at the ends, and in this particular species are plumose at the ends. The distinguishing marks of the male in this case, as in others, are the large plumose antennæ—regular whiskers, as befits the sex. The adult insects can thus be distinguished, but for complete identification this is not enough. Various markings of the legs and palpi, and the arrangement of the wing and body scales, are used to

identify species. The shape of the eggs is different in the two genera, those of the *Anopheles* possessing a distinct boat shape, while *Culex* eggs are blunter for the most part. They are laid in masses of from 200 to 400. These eggs develop in the course of from 12 hours to several days into larvæ, which are known to every boy as the "wigglers," found in every tank and pool in fairly warm weather. Here we note another difference in the genera, the *Anopheles* lying parallel with the surface owing to the absence of the long breathing tube, which enables *Culex* to hang down from the surface—the direct opposite of the position assumed by the adult insects, as you will recollect. The arrangement of the hairs upon the different segments enables species to be determined. In a week for *Culices* or more for *Anopheles*—the time varies considerably in these processes for different species and under different conditions—the active wiggling larva after develops into a pupa, which again differs in the two genera, and after a varying period of from two to 10 or more days the pupa case splits down the back, the adult insect emerges, and after balancing itself on the empty case for a while in order to dry its wings, flies away to propagate its kind in turn.

To sum up the points which I have endeavored to briefly indicate we have the following facts to consider wherever malaria is to be dealt with. There is firstly a blood parasite, which is the cause of the disease, and next come particular species of a particular genus of mosquito, whose tissues afford the only place wherein this parasite can complete its life cycle. Malaria can be conveyed from man to man by injecting blood in which the organism is, but this need not be considered in practice. Therefore, in tackling the question of stamping out malaria we naturally attack the mosquito. The adult insect may be guarded against by mosquito curtains and other measures to prevent its biting—a particularly useful one by the way consists in wearing two pairs of socks after dark, a thick pair underneath and a thin pair on top, since more people are perhaps infected at the dining table than in almost any other way, the *Anopheles* loving the dark lurking-places under that cheerful board. It may also be killed by

fumigation with sulphur or pyrethrum powder. This, however, is an incomplete way, and since the *Anopheles* breeds by preference in small puddles and shallow stretches of weedy swamp or slowly moving water free from small fish, its destruction is rather an engineering than a medical question. Much may be done by pouring kerosene and paraffin on the surface in the proportion of about a tablespoonful to every square yard of surface, so as to form a thin film, which clogs the air tubes of the larvæ and pupæ, and also kills the adult female while depositing eggs. This remedy will be found efficient by those of you who are worried by the local *Culices*, which evince a bloodthirsty disposition in Newtown, at any rate. *Culices* are especially fond of small collections of water in pots and saucers—the saucer of a flowerpot on a window sill may provide sufficient mosquitoes to make the inmates' life a misery, while an ordinary 400 gallon tank will stock a neighborhood.

The moral of which, as Captain Cuttle is recorded to have remarked, lies in the application thereof. I need not say more than that the notoriously malarious localities of Sierra Leone and Freetown, formerly known as the "white man's grave" in West Africa, have, comparatively speaking, been turned into health resorts within two years of organised effort against mosquitoes, and that at Ismailia, in Egypt, a previously notoriously malarial town, the average number of cases has been reduced from 2000 to 200 per annum by one season's work. Practically, there were no fresh cases of malaria once the work was got going, and it is now possible to sleep there in safety without a mosquito net, probably for the first time in the history of the town. Probably everyone here to-night has been at one time or another subjected, unasked, to the gastronomic attentions of a female mosquito, and the method in which she performs the operation after a preliminary song may be a more or less interesting memory on the next occasion you commit *culicide*. (The lecturer here described with a lantern diagram the manner in which the mosquito feeds).

So far we have considered the corporeal life of the malarial organism, that is, the part of its life-cycle which is passed in the blood of man, with

the single exception of that octopus-like male gamete which, as I pointed out, only develops after leaving the human body. Turning now to the second, or extra-corporeal stage of its life history—i.e., that stage which, as we now know, is passed in the mosquito—we find that there are really two forms of cell developed amongst the organisms, one the octopus-like male gamete, the other a spherical cell. Now, it is only when the *Anopheles* takes in blood containing parasites at, or about this particular stage of development, that it becomes infected with malaria, and capable of conveying it to fresh human beings, a fact which accentuates the importance of protecting malarial patients by means of mosquito nets wherever possible. Having taken in the blood, however, by means of the complicated sucking apparatus, which I have described, the gametes develop into the sexual form, and the true function of the male's loose arm becomes evident since it joins with a spherical cell formed by another gamete, and impregnates it. It was the female gamete which it was in search of when it cast loose. Then the fertilised cell or zygote attaches itself to the stomach wall of the mosquito, bores its way through, grows greatly in size, and proceeds to divide into a great number of tiny cells. It becomes a cyst, which finally bursts and sets free the tiny structures within, which have meanwhile developed, and these, set free in the body cavity, settle in great part in the veno-salivary gland at the base of the proboscis, as tiny thread-like bodies, termed zygotoblasts or sporozoites. The gland in which they lie is that which secretes the irritating substance of which we all know the effects in connection with a mosquito bite, and in the case of an infected *Anopheles*, they are injected with this secretion along the proboscis. The process for their development in the mosquito takes about 12 days from the date of the meal of infected blood, before the thread-like bodies appear in the gland. After injection, along with the secretion, the sporozoites infect the blood corpuscles, grow rapidly, and break up into spores which in time infect fresh corpuscles, until a huge swarm of parasites, with a life cycle of either 48 or 72 hours is produced in the blood. The breaking-up of each swarm sets free

the fever-producing substances which produce the symptoms of malaria. I have given but a rough outline of the process, but it will serve to show the main points of this complicated life-history.

It will be seen, however, that the process of infection by *Anopheles* is *not* a simple mechanical transference of blood from infected to healthy people, that human cases can only infect the *Anopheles* at a particular stage in the history of the parasite in their blood, and, particularly, that an *Anopheles* which does not bear in its poison gland the thread-like spores of malaria representing the last stage of the extra corporeal cycle of the organism passed within its body is as harmless as an empty gun.

It will be readily understood that the work of Ross and his colleagues in other parts of the world gave a huge impetus to the study of insect-borne diseases, and it has borne noble fruit. The connection of Yellow fever with Havana is almost proverbial, and the average deaths from that disease alone were over 800 in each year. It has been estimated that some 36,000 persons died of it from 1853 to 1900, and in addition the island of Cuba and adjoining parts of Brazil acted as an endemic focus, whence, at various times, the disease spread to many parts of the world, including Spain, Africa, and even England. In 1897, there were 6000 deaths from it in Cuba. In Rio from 1868-1897, 41,726 deaths. The Southern States of America have also experienced dreadful visitations from it. "Yellow Jack" was a dreaded name throughout South America, the West Indies, and the Southern United States. With the opening of the Panama Canal and the consequent shortening of the voyage from these localities to Australia and the Far East, it is very probable that Yellow fever will some day be introduced to this side of the world. Three or four years ago, Australian sanitarians regarded this possibility with awe and foreboding; to-day they look upon it certainly as a serious problem, but as one which would give comparatively little trouble compared to the introduction of a few cases of small-pox. I will endeavor to explain how this remarkable change in views has come about.

In 1900, after the occupation of Cuba

by the American forces, a commission of four medical men was appointed to investigate the alarming prevalence of Yellow fever there, and to devise, if possible, means for combating it. A great deal of work had been done by various observers in seeking for the cause of it; but nothing was accurately known, and the early work of the commission, devoted to the examination of the blood and tissues of patients, only served to disprove previous theories, and not to discover anything new. Absolutely nothing was apparent in the blood or elsewhere as a result of the most careful bacteriological research. The next step was to enquire into its propagation. Now, one attack of Yellow fever safeguards the patient against a second one, producing a condition of immunity, as it is called. It had been noted that patients could be safely nursed by non-immune nurses, and that patients discharged after an attack did not cause fresh outbreaks of disease in those non-immune persons they came in contact with. It was obviously, therefore, not contagious, nor did the infection persist in a virulent form in the discharges. The next matter was to settle the disputed question of the infectivity of clothing and bedding which had been in contact with patients. To this end, a small hut was erected, very deficient in ventilation, and specially constructed so as to maintain a hot moist atmosphere within it. The windows and doors—please note this—were carefully screened with fine wire gauze, of small enough gauge to prevent the entry of mosquitoes. Into this house were piled sheets, blankets, mattresses, pillows, and clothing of all description from the Yellow fever hospitals, and amongst them, in the beds and covered with the bedding of patients, who had just died of Yellow fever, even wearing the clothing taken from the bodies, and stained with the blood and "black vomit" discharge, seven young non-immune Americans, including members of the commission, slept two or three at a time for a total period of sixty-three nights in all. Not a single one of these non-immune men developed the disease. This effectually proved that clothing and bedding alone were incapable of conveying the disease, however grossly they were contaminated.

The next step was to enquire into the question of insect transmission. A common domestic mosquito of Cuba is the *Stegomyia fasciata*, a strikingly marked insect of voracious habits, and suspicion had already attached itself to it. Both sexes of it suck blood, and it is probably the most widely distributed of all mosquitoes, being found practically all through the tropical world, and also in many sub-tropical localities. Twelve plucky young Americans, two of whom had taken part in the experiments with clothing previously described, volunteered as subjects. All these were living under exactly the same conditions as scores of other non-immune residents of the camp, and the two I have mentioned had been free for 30 days from their self-imposed imprisonment in the infected clothes hut. All were deliberately subjected to the bites of specimens of this mosquito, which had been previously allowed to bite early cases of Yellow fever. After periods of from three and a-half to six days from being bitten, all except two developed true attacks of Yellow fever.

One experiment in the batch was of especial interest. A newly-erected building was divided into two parts by fine-wire screens. In one part were let loose 15 infected mosquitoes, and in the other half, separated only by a wire screen, two non-immune men lived and slept. The volunteer subject entered the part in which were the mosquitoes on three occasions of about twenty minutes each, and was freely bitten on each occasion. On the fourth day after his visit he developed a severe attack of Yellow fever, while the two men in the part on the other side of the gauze screen continued for 18 nights to sleep in and breathe the common atmosphere of the room without any ill effect. This was pretty fair evidence even for the scientific mind that the mosquitoes were the conveyors of the disease, and subsequent experiments proved this to be so beyond all doubt.

The organism which is the actual cause of Yellow fever has not been discovered, probably because it is so minute as to escape the highest powers of the microscope. This is the more likely since, as in the case of malaria, the injection of blood from an acute case will produce the disease in a

non-immune subject, but, unlike malaria, the blood remains similarly infective after it has been passed through the finest Berkfeld filter, thus proving the extreme minuteness of the organism, since such a filter will stop the smallest of known bacteria. That it is not a bacteria, but an organism more of the type of the malarial organism is very probable from the fact that the infection cannot be obtained by the mosquito from the blood, except in the first three days of illness, and the mosquito does not become capable of infecting fresh persons until 12 days or more after it has fed upon a case at this particular stage. The fact that an outbreak of Yellow fever took a fortnight or so to light up after the introduction of a case into a locality had long been noticed, and this explained the reason thereof.

Having obtained these facts, the battle against Yellow fever assumed a new aspect. Huge sums had been spent during previous years in indiscriminate disinfecting of articles which had been in contact with Yellow fever patients—quite harmless as we now know—and in other expensive measures, absolutely without avail. The campaign was now begun by a wholesale destruction of mosquitoes and their breeding places in swamps and puddles, and by the careful screening of Yellow fever patients for the three first dangerous days, from mosquito bite in order to prevent the loading up of fresh winged carriers of disease. Quarantine of cases was given up—it had been enforced for many years without avail,—and the only quarantine order was that of the mosquito net. The result was amazing. In ninety days from the commencement of operations Havana was freed from Yellow fever for the first time in 140 years. Repeated introductions from without, where the measures were not in force and where Yellow fever was raging unchecked, as it had done for decades past at that season, were promptly stamped out, and the fact was realised that although every effort known to sanitary science had been put forth without avail up to March, 1901, the change effected in the measures by the recognition of the mosquito as the carrying agent had enabled the authorities to obtain in 13 weeks a result which had defied the efforts of

more than ten times as many years. Epidemics of Yellow fever, thanks to those able and heroic American doctors, are a thing of the past in civilised countries, and the name of Dr. Lazear, who contracted the disease and died of it during the enquiry, another of the numerous martyrs whom science has claimed, will always occupy an honored place in the scroll of hygienic fame.

I will not do more than give the outlines of certain other work which has been carried out in this direction. The recent investigations which have been made into Sleeping sickness—that strange disease which overwhelms its victims with an increasing languor and somnolence until they perish of an apparent failure of all the faculties—has received a good deal of notice in the press. The researches of Dr. Castellani, Dr. Bruce, and others, go to show that the conveying agent in this case is the Tsetse fly, previously well known for the fatal effects of its bite on horses and cattle, but only lately known to be connected with disease in human beings. The mortality from Sleeping sickness in certain parts of Africa has been alarming, and whole districts have been decimated by its ravages. The causative agent appears to be a form of organism known as a trypanosome, or, as it should be more correctly termed, a herpetomonas, which lives in the blood and fluids of the victim. Further work yet requires to be done, but little doubt remains that the curious and fatal disease which almost invariably kills its victim, and which has been known as a scourge of Western Africa for over 100 years, has been brought within the grasp of science, and will be dealt with as effectually as malaria and Yellow fever are being dealt with. Whether the organism undergoes a part of its life history within the Tsetse fly's body is not yet definitely settled by actual observation, but it seems probable that it does so.

The presence of plague in Australia renders its causation and spread a matter of perhaps more acute interest than the exotic diseases with which I have been dealing. The causative agent is, of course, a well-known bacillus, but the means whereby it is habitually conveyed to human beings to infect them have been widely discussed amongst scientific men, and there is a growing tendency on the part of those who

have to deal with this disease to regard more and more suspiciously a certain insect which already possesses an evil reputation in domestic sanitation; I allude to the flea. A good deal of work has been done on these insects of late years, and it may surprise you to learn that more than 130 distinct species of flea have been classified, and that new ones are coming into knowledge month after month. Remarkable differences are found in their structure and habits, but in the particular connection with which we have to consider them to-night, one genus attains prominence—the true pulices of which the type is the human flea.

Now, in considering the histories of plague outbreaks in different parts of the world, one is at once struck by a curious fact, namely, that while preceding or simultaneous outbreaks of the disease amongst rats and other small rodents, have formed a marked feature of plague epidemics in the East, nothing of the kind has attracted the attention of the chroniclers of the European outbreaks of the middle ages, and of the great plague of London in 1665. The phenomenon is striking enough to attract the attention of any ordinary observer where it occurs, and a significant allusion to it is to be found in the First Book of Samuel. Other and even more definite allusions occur scattered through Eastern literature from a very early date, so that it appears to have attracted attention, and could scarcely have escaped the acute chroniclers who have left us such a vivid picture of medieval and seventeenth century plague. It is needless to remind you that the same phenomenon occurs in Australia and in South Africa at the present day. The domestic rats of the East, of Australia, and South Africa are very similar to those of Europe, and all readily contract plague when infected experimentally. But on examination of their parasites a curious fact was noticed in that the common rat fleas of Australia, of India, and of South Africa are widely different insects from the common rat flea of Europe, both in structure and habits. They are very closely allied to the human flea, so closely, in fact, that their relative identification is a matter of extreme difficulty, without previous acquaintance with the genus, and the Indian and Australian

varieties, will, on occasion, act as parasites to man, and will bite vigorously. The common European rat flea, or *Ceratophyllus fasciatus*, on the other hand, differs in important structural respects, and can, only with great difficulty, be induced to feed on man. Does it not appear to be something more than a coincidence that where we find a rat flea closely allied to the human flea, there we have plague amongst rats as well as man, whereas in places where the rat flea varies widely from the human flea the occurrence of epidemic rat-plague is, at any rate, not an important phenomenon.

The theory was for long held that the plague bacillus lives and multiplies in the earth, but out of innumerable attempts at its recovery from the earth-floors of plague-infected Eastern hovels, but a single success has resulted under natural conditions. As in the case of Yellow fever, it has been stated to have been spread by infected clothing. It probably is so spread, but in some other way than the mere bacillary infection of such clothing, for the plague bacillus has never been recovered from infected clothing, unless in cases of gross experimental contamination. Plague is particularly a disease of locality, and especially tends to infect those who sleep in such a locality, sparing those who move actively about during their visits and sleep or rest elsewhere. It chooses dark, squalid, vermin-haunted vicinities, and avoids to a great extent airy, well-lit places. The experience of plague hospitals is a curious one, for whilst, in ancient days, even a short visit to a pest-house was attended with great danger, it is rare for an attendant in a modern plague-hospital to be attacked. That the disease itself has not varied from ancient times we know from contemporary records, but whilst the modern hospital is especially built with a view to cleanliness, light and airiness, the ancient hospitals seem to have combined all the hygienic offences of its day. To sum up we have certain facts which seem to point in a particular direction. Plague does not, apparently, thrive in the soil, nor is it known to enter the body with the food, in human cases at least. In the ordinary form—excluding plague pneumonia—it enters by the skin, and in the bubonic form it certainly enters in the lymphatic area drained by the first affected

gland. Water plays no part in its dissemination. Meteorological factors have no influence except in one significant indirect instance—that in India the plague mortality is noticed to rise materially after a cold night, or a heavy fall of dew, and especially after rains during the dry season, whereby people are driven into their homes instead of sleeping outside as usual. Clothing is apparently capable of conveying the disease; but the bacillus is not recoverable from clothing. And lastly, a marked association of the rat with plague outbreaks has been noticed since remote periods in parts of the world where the rat flea closely resembles the human flea, and no such association where the rat flea shows, at any rate at the present day, wide structural differences from the human flea.

This circumstantial evidence appears to incriminate the insect, but circumstantial evidence is not enough. Dr. Simond, in 1897, had proved that by infecting into a mouse broth in which fleas had been emulsified, after having fed on a plague-stricken animal, plague could be produced in that mouse. This experiment was successfully repeated on several occasions by myself and others, and the results obtained were sufficiently encouraging to induce further work. Fleas of certain species were fed on plague-infected animals, and after varying periods of starvation were allowed to bite healthy rats under conditions which excluded any probability of the disease being contracted otherwise than by flea-bite. These rats died of undeniable plague, and it was found that the flea could convey plague in this way up to at least three days after a meal of infected blood. There is no reason why it should not do so for very much longer. It was found that in one case, at least, this conveyance from rat to rat was effected by a human flea. In other cases the rat-pulex was used. A further experiment was performed in which plague was conveyed from a human being to two rats by means of fleas. This latter experiment was of especial significance, since, on subsequent examination, it was found that while three of the insects used for the purpose were the *pulex pallidus* of rats, one was a *pulex irritans*, or human flea. By cutting the insects in sections after a

meal of infected blood, and examining them under a microscope, large numbers of bacilli indistinguishable from plague bacilli in their microscopical characteristics, were found in a peculiar organ forming a part of the œsophagus; while in fleas, which had been fed on healthy blood, no such bacilli were found.

The work which I have alluded to was performed in India certainly with all the facilities of one of the biggest bacteriological laboratories in the world, but without much assistance from special literature on the subject, for the very good reason that none existed to indicate the technical difficulties to be overcome. As you may readily imagine, these were considerable, for to secure such an active and minute creature as the flea in such a manner as to allow it to feed, and yet to ensure that it should not get away after its dangerous meal of plague infected blood, was an operation of no little difficulty, and also of some danger, both to the experimenter and to his neighbors. After a good deal of trial, the device was hit upon of confining them in a glass tube—an ordinary test tube was used—and covering the open end with a cap of fine gauze, through the meshes of which the flea could protrude its proboscis, but could not escape. This difficulty overcome, it was necessary to find some distinguishing marks by which to identify the species used. This was affected after a time, and the few species employed were readily enough identified.

The habitual spread of plague by fleas of the type I have shown you is not to be taken as a universally accepted fact, but strong evidence exists that this will eventually prove to be, at any rate, an important factor in epidemics.

You may recollect an allusion made to the work of Dr., now Sir, Patrick Manson, in relation to certain blood worms, which are fairly common amongst human beings in the tropics. No less than five different kinds of these worms are known, and one in particular, the *filaria nocturna*, so called because it is only found in the blood during sleeping hours, is of particular interest, in that it causes a good deal of illness by blocking up the delicate lymphatic ducts, and is almost certainly in this way the cause of that strange disease elephantiasis. *Filariæ* occur amongst other tropical and

subtropical places in Queensland and Northern Australia to about the latitude of Brisbane, and the manner in which the *filaria nocturna* completes its life cycle is of interest. The parent female worm is some 4 in long, and lives in some part of the lymphatic system, in company with the male, which is slenderer and smaller. There she produces a great number of embryos, which make their way into the blood, and live during the day in the vessels of the internal organs. About 5 or 6 p.m., in infected persons who do their sleeping at night, they begin to appear in gradually increasing numbers in the peripheral circulation, or vessels in the extremities and at the surface, increasing till about midnight, and then decreasing, until about 8 or 9 in the morning they have all disappeared from the peripheral blood for the day. It is a curious fact that in infected persons, who do their sleeping during the day and remain awake at night, the embryos reverse the time of their appearance, and turn up during the day in the peripheral vessels, disappearing at night. Each embryo is about 1.80 in long, and is contained in a loose sheath or sack somewhat longer than itself. They are very active organisms, and wriggle about strongly, but the sheath keeps them from changing their position much; in other words, they are not locomotory. The function of the sheath is to keep them from using the strong boring apparatus which they have on their heads, and so escaping from the blood vessels. As I have said, they appear in the surface blood vessels at night as a rule, and this is obviously for the convenience of the conveying mosquito, which principally feeds at night, and into whose stomach some of the embryos are taken with the meal of blood. The ordinary mosquito so acting is a species of *Culex*, and in its stomach the blood becomes much thicker by coagulation. The embryo within the sheath is thus able to get a purchase on the sheath, and eventually to ram its way out through one end by butting vigorously while the sheath is stuck fast in the thickened blood. Of course, while the blood was fluid in the human host's vessels, it could not do this because the sheath could only be bumped along by its efforts from within and would not split.

Once loose it bores through the stomach wall of the mosquito, gets into the muscles, and changes its form very considerably. Finally, after some 16 days, it appears in the head and proboscis, not in the poison glands as did the sporozoites of malaria, but coiled up under the pharynx and in that part of the proboscis known as the labium. They can remain here for an indefinite period awaiting the chance to pass into the tissues of a warm-blooded vertebrate when the mosquito takes its next meal of blood. Apparently they can discriminate, for no amount of feeding of the insect on bananas or other fruit (upon which it ordinarily subsists, will cause them to come out. When, however, the insect sticks its proboscis into a human being the filariae find their way through a weak spot which exists in the labium where the labellae splay out, and pass along the track of the proboscis into the tissues of the victim. The filariae apparently endeavor to emerge in pairs, male and female, and upon establishing themselves in the tissues of their new host, they set up housekeeping, and begin again the process of which we know the results under the name of the filariasis, be it elephantiasis or any of the other peculiar conditions by which we recognise the blocking of the lymphatic channels by their offspring.

I trust that I have been able to give some indication of the very prominent part played by certain insects in certain exotic diseases, but there is little doubt that they also assist in disseminating others which are with us already. The ordinary house fly is ubiquitous in its habits and unpleasant in his history and associations. That it is capable of conveying on its feet and body the germs of disease under experimental conditions has been demonstrated and that it frequently does so in nature is freely admitted. In a more enlightened age the housewife will regard flies with the same horror and disgust as she now regards bugs and fleas, and most thinking folk will even now cordially agree with her in theory if not in

practice. From the time in which it is engendered in a heap of manure to the fateful hour in which it commits suicide in the milk jug, or perishes in the sticky recesses of the summer butter pat, the life of the average fly is passed amidst more than questionable surroundings. Its ubiquity renders the whereabouts of its last alighting place a subject for uncanny speculation when it settles on an article of food, and I have little doubt that domestic flies, so-called, are responsible for a fair proportion of cases of communicable disease, especially perhaps of typhoid fever. Its possibilities, however, do not end there; exanthematous diseases, especially perhaps smallpox, may be readily conceived as spread by this means. I confess in fact to a doubt as to whether the real cause of the aerial convection of smallpox is not partly or wholly due to insect life. Many points in the available evidence upon it appear to render such a hypothesis tenable, and fly-proof door and windows coverings should certainly form a part of the furnishing of isolation hospitals for this disease.

The possibilities of this line of research are, however, boundless, and in time to come the labors of the biologist and naturalist will become of more and more importance from the standpoint of human disease. The extension of research in connection with cancer in the lower animals has resulted in its discovery in a large number of creatures, including even fish. Similar results have been obtained with the tubercle bacillus, whose range appears to be practically universal. The diseases of which I have spoken to-night do not by any means include all those in respect of which insects are known, or suspected, to play an important or essential part, but they will serve as illustrations of the pioneering work which has been, and is daily being done by many investigators in different parts of the world for the benefit of humanity and the advancement of civilisation.

The lecture was illustrated by lantern slides.